DECISION SUPPORT SYSTEM FOR NTEGRATED PRODUCTION-DISTRIBUTION PLANNING FOR CONSUMER GOODS

by

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INDIAN INSTITUTE OF TECHNOLOGY KANPUR

FEBRUARY, 1991

CERTIFICATE

It is certified that the work contained in the
entitled "**Decision Support System for Integrated**
tion-Distribution planning for consumer goods " by
ra **Kumar Dangi** has been carried out under my supervision
s not been submitted elsewhere for the award of a degree.

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ABSTRACT

In this thesis, the development of decision support m to help the management in taking production and ibution planning decisions in a consumer goods industry has dealt with.

The planning process consists of making the following ions :

. The identification of quantity of the products allocated to various production centers.

:. The Master Production Schedule for each production center.

. The location of intermediate buffer depots for temporary storage of the products.

. The inventory allocation to the available space.

. The vehicle dispatch policy and route determination.

The mathematical structure of problem is considerably to solve on micro computer. The strategies has been loped to decompose it into sub-problems of considerably small . Wherever the size of subproblem is observed to be large, istics are developed.

A decision support system for the above problem has developed to make the user interact with the system, while ng decisions. The system has been developed to be used on a computer and be user friendly.

ACKNOWLEDGEMENT

I owe a deep sense of gratitude to Dr. A. K. Mittal for ınce, valuable suggestions and constructive criticism ɔm selection of topic to preparation of thesis. He gave of time in his tight schedule to keep on the right he language of conscience has never been exactly ɜd into words and i am facing the same dilemma.

I am indebted to all my teachers for providing the ɔn to the thesis work.

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CONTENTS

		PAGE
)F FIGURES		vi
'RODUCTION		1
(	Decision support system	2
?	Production Planning	4
3	Distribution planning	4
	1.3.1 Location-allocation of warehouses	5
	1.3.2 Vehicle routing	6
4	Integrated production-distribution planning	9
5	Problem definition	10
6	An overview of the thesis	15
JBLEM DECOMPOSITION		16
1	Problem decomposition	16
2	Demand allocation	18
	2.2.1 CFA demand allocation to production centers	18
	2.2.2 Time period wise disaggregation of allocation.	23
3	Production planning	25
	2.3.1 Aggregate production planning	26
	2.3.2 Master production schedule	29
	2.3.2 Production allocation to CFA	36
4	Distribution planning	38
	2.4.1 Warehouse location allocation	39

2.4.3 Vehicle routing 42

;TEM DESIGN AND IMPLEMENTATION 43

. System design 43

3.1.1 Information required by system 44

3.1.2 Strategic information 46

3.1.3 System component selection 48

3.1.4 Output generation 49

3.1.5 System organisation 49

2 System implementation 59

3.2.1 System components 59

3.2.2 System linkage 60

3.2.3 Data structure 61

ER MANUAL 62

1 Getting started 62

2 Input requirement 63

4.2.1 Permanent information 63

4.2.1 Temporary information 67

3 System execution 68

4 Transparent files 69

5 Output 70

NCLUSION 74

'PENDYX 76

FERENCES 78

LIST OF FIGURES

O.	TITLE	PAGE
	Conceptual view of DSS.	3
	Route components	7
	Integrated production distribution planning	10
	Organisational structure of DREAT CO.	11
	Linkages amongst various sub-problems in IPDP.	17
	Profiles of production plan	27
	Product wise disaggregation of production	33
	Program linkage	60

INTRODUCTION

In companies oriented to consumer goods, the :ion of goods plays a role as important as the production. ·ibution of goods is linked with the production, hence ·d **production distribution planning** (IPDP) becomes an function.

In this thesis, which is continuation of the work done [17], we shall discuss the design and implementation of **Support System** for production and distribution planning lti product, multi production center consumer goods company. Specifically the problem situation is based on large food product company with a nation wide market.

Usually in this industry, the customer demand are met by ber of traders, whose requirements are supplied by the rom it's distribution center serving the locality. The ion center will get it's supply from the production warehouse.

Generally the company's distribution planning is limited ›ly of the goods to distribution center. Based on the :tern of the distribution centers, the production plan to quantum of various products at production centers is The distribution plan, which involves allocation, ınd routing of goods from production center to on centers, is linked with the production plan. Since l of products changes with the time period due to

nature, planning becomes a complex process.

The basic framework for such an integrated production :ion planning (IPDP) is structured by *Shyam* [17]. The in this thesis is given on development of decision ystem for this framework. Most of material in this s common with *Shyam* [17] and is given here only for sake uity.

DECISION SUPPORT SYSTEM

A computer based system which helps decision maker, ata and analysis models to solve unstructured problems as **decision support system (DSS)**.(*Sprague & Watson* [18])

DSS is focused higher in the organization with an on the following characteristics :

- Decision focused, aimed at top managers and executive decision makers.
- Emphasis on flexibility, adaptability and quick response.
- User initiated and controlled.
- Support for personal decision making styles of individual managers.

The benefits provided by DSS are often qualitative in ıme of these includes the ability to examine more 'es, stimulation of new ideas and communication of

Criteria for a system to be DSS :

Support but does not replace decision making.

Directed towards semi- structured or unstructured tasks.

Data and models organized around decisions.

Easy to use software interface.

Interactive processing.

DSS use and control is determined by user.

Flexible and adaptable to changes in environment and decision making style.

Support all phases of decision making process.

The conceptual view of DSS is given in Fig. 1.1 .

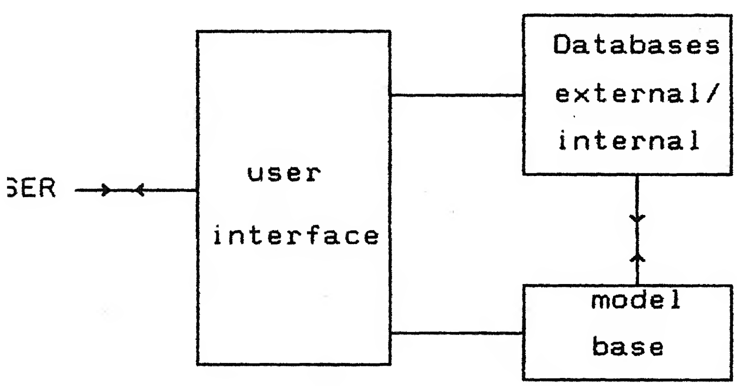

FIG. 1.1 Conceptual View of DSS.

Here database consists of factual knowledge concerning ndustry (internal and external). The model base may rious management science, statistical, economic and odels. The user interface and display is a mechanism to ease of use between the models, databases and the user.

1.2 PRODUCTION PLANNING

The activity of establishing production goals over some future time periods *i.e.* planning horizon, to meet the stated requirements by optimal use of resources is known as **Production Planning**. The production planning decisions have impact on the cost of product and are linked to distribution planning as the shipments are dependent on the production.

The production planning model can be classified into static and dynamic one depending upon the demand profile. The production planning models include product mix problem, process selection problem, blending problem and so on.

Extensive literature is available on production planning including several excellent books such as *Johnson & Montgomory [12], Bedworth [1], Vollman [19],Buffa & schubert [5]*.

1.3 DISTRIBUTION PLANNING

The purpose of the distribution planning is to efficiently distribute goods from production center to the customer. Prevailing practice in the industry under consideration is to store goods at the distribution center controlled by company from where the retailers get their supply to meet customer demand. Thus distribution planning consists of distribution from production center to distribution center directly or through intermediate warehouses necessitated due to space limitation or routing consideration. The major decisions involved in the distribution are of two types :

A) Location of warehouses and allocation to distribution

centers.

B) Vehicle routing of actual supplies to distribution centers and warehouses.

1.3.1 LOCATION - ALLOCATION OF WAREHOUSE

Location decisions are particularly important because once they are built, managers must live with them for a long period. It is observed that there is no clear-cut best location, but rather there are several good locations. Typically several site candidates, each with it's strength and weakness, emerge as a good choice and location decision becomes a trade off between conflicting objectives.

The allocation problem involves the identification of distribution centers the warehouse can cater to. The dominant factors which affect the decision are transportation and storage costs.

Cooper [7] approached the problem by fixing a number of locations and determining the minimum cost solution for all the possible combinations of allocations. Since the number of combinations for moderate to large sized problems are too large, the procedure is not feasible.

Love and Juel [13] developed fine solution methods, that utilizes the special properties of location allocation problem. The algorithm first finds a local minimum of the combined location allocation problem. A local minimum is defined as a set of locations and allocations such that the locations are optimal with respect to allocations and vice-versa. The solution is perturbed

by changing the allocations systematically.

Cooper [6] has discussed several heuristic methods for location allocation problems.

Nagelhout and Thompson [14] used a cost operator approach to obtain a grading solution for multi stage location allocation model. The algorithm takes the advantage of network structure of supply and demand constraints and the sub modularity of the objective function.

1.3.2 VEHICLE ROUTING

The shipment of products will be generally done in truck loads. The distribution cost generally depends on the distance travelled by the vehicle and size of the vehicle. Thus a partial shipment is likely to cost the same as a full truck load. Under such circumstances the transportation cost can be reduced drastically by multiple destinations of vehicle and identification of best route.

The determination of routes involve many other factors related to time. The more the destinations in a route, greater the stop time for vehicles.

The delivery operations may be divided into three major components stem distance (SD), stop time (ST) and variable running distance (VRD). ST is function of only shipment characteristics. The SD is the sum of the distance from origin to the Ist destination on the route and from last destination back to the origin. The VRD is the source of dependence between the cost of delivering to any given destination center and the occurrence of

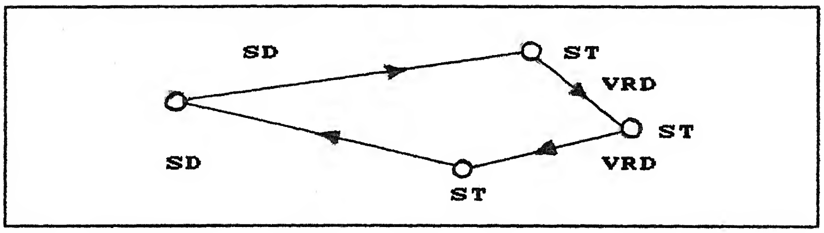

FIG. 1.2 Route Components.

other deliveries. Both SD and VRD depends on the vehicle routing.

Since the transportation costs in the location allocation consists of the incoming and outgoing transportation costs, the inter dependency between location allocation problems and vehicle routing problems exists.

In the incoming operations, the products flow into the warehouses from production center. Here, the locations of warehouses affect the VRD as well as SD (Fig. 1.2).

In the outgoing operations, products flows from warehouses to distribution centers. Here, the SD represents the affect of the locations of warehouses on delivery costs. Further, the allocation of the demand centers also affects the VRD in the outgoing operations from the warehouses.

The routing via warehouse imply a hierarchical one. The *Ist* level routing consists of the dispatches from the production center to warehouse and distribution centers. The I*Ind* level routing consists of the dispatches from the warehouses to the distribution centers.

Most vehicle routing models are extension of the Travelling Salesman Problem (TSP). In TSP, the problem is to form a tour of the number of nodes beginning and ending at the origin. Extensive overview of this problem has been given by *Bellmore and Nemhauser [2]*.

The multiple travelling salesman problem comes closer to accommodating more real world problems, where given N nodes and M salesman in a network, the aim is to find M sub tours (each including origin) such that every node except origin is visited exactly once and only by one salesman, so that the total distance travelled is minimum.

The technique for solving Vehicle Routing Problem (VRP) forms two classes, one the problem is solved exactly and other by heuristics. The exact techniques are viable only for very small problems. The heuristic approach falls into two categories one is 'cluster first route second' and the other is 'route first cluster second' approach.

In the cluster first route second approach demand points are grouped into tours by some way and then TSP is solved for each group. A efficient algorithm by *Gillet and Miller [9]* uses this approach.

Bodin and Berman [4] used the route first cluster second approach for routing school buses. In this, a large route is constructed which includes all the demand entries. Then, the large route is partitioned into a number of smaller but feasible ones.

Fisher and Jaikumar [8] gave a mathematical programming

based procedure. They formulated VRP as a mathematical program in which two interrelated components are identified, one is TSP and other generalized assignment problem.

Golden et al [10] gave a detailed description of the heuristic algorithms for VRP. *Perl and Daskin* [16], *Nambiar et al* [15] proposed heuristics for the location of the warehouses and routing of vehicles to the distribution centers.

Jacobson and Madson [11] compared three different heuristics for a two level routing location problem for a newspaper distribution system, where the decisions are to be made on the number and locations of intermediate points, design of tours originating at the origin to serve the intermediate points and design of tours emanating from the intermediate points to the destinations.

1.4 INTEGRATED PRODUCTION DISTRIBUTION PLANNING

The various decisions viz. quantum of production, allocation of inventory and routing decisions discussed till now are based on the implicit assumption of single production center. If there are more production centers, then the major decisions involved will be identification of the origins (production centers) which will cater different products to the distribution centers. Since there is an inter dependency between the decisions, the identification of origins can not be viewed in isolation from other decisions. The considerations involved in a IPDP are shown in Fig 1.3 .

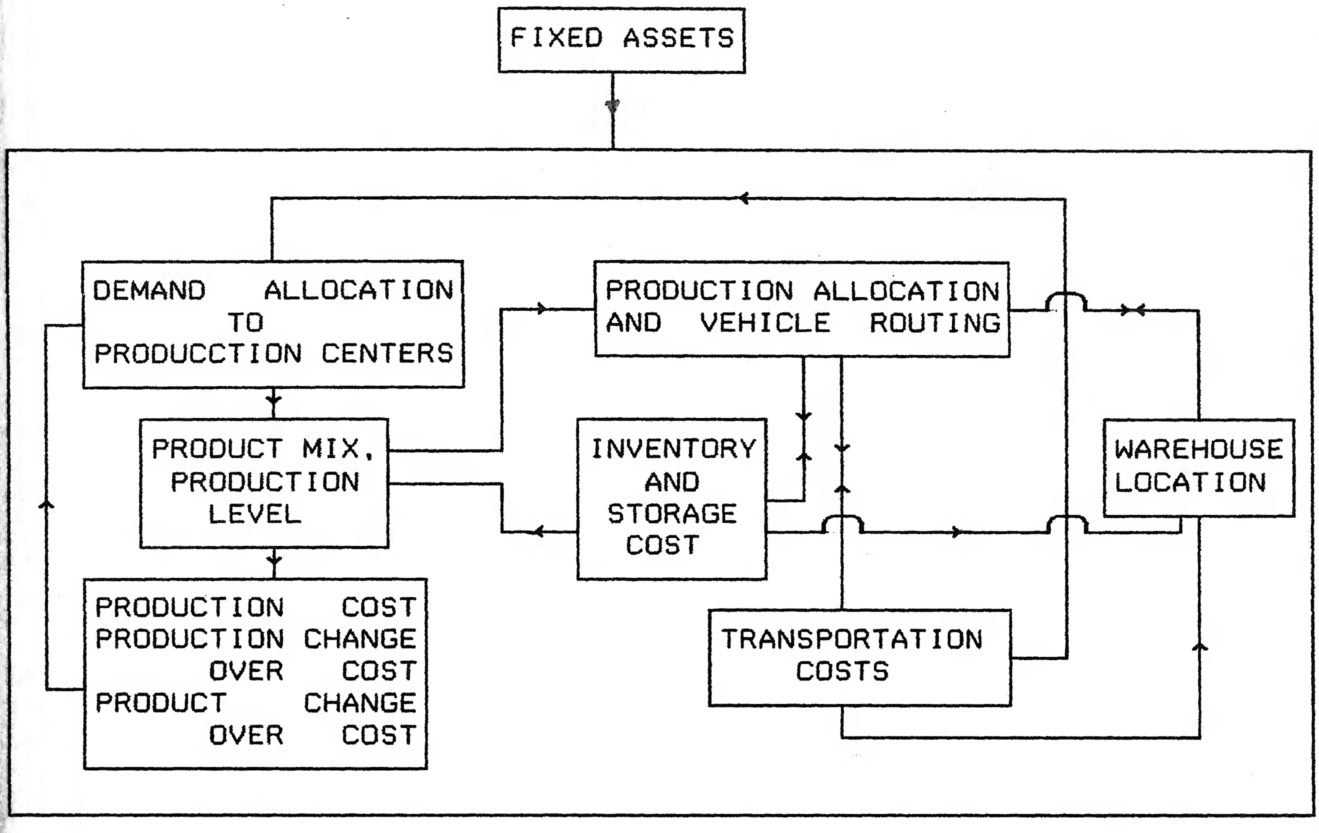

FIG. 1.3 Integrated Production Distribution Planning. (*Shyam*[17])

There are very few papers available in this area. *Blumnfield et al* [3] tried to determine optimal shipping strategies on freight networks by analyzing trade-off between transportation, inventory and production set-up costs. Networks with direct shipping, shipping via a consolidation terminal and a combination of terminal and direct shipping were considered.

1.5 PROBLEM DEFINITION :

A hypothetical company DREAT CORPORATION was taken for the specific problem of Integrated Production-Distribution

Planning. The attempt was to model a Decision Support System for Production and Distribution planning of a consumer goods oriented, multi product - multi production center company with a nation wide distribution network.

The company is engaged in production and distribution of two different types of food products called DRINK and EAT. Each food product is marketed in different flavours and packages, while most of the raw materials are common. Each product has a specific shelf life. The company has a no. of production centers which can produce either the DRINK or EAT. Further while most of production centers can produce all, others are restricted to produce specific flavors and packages.

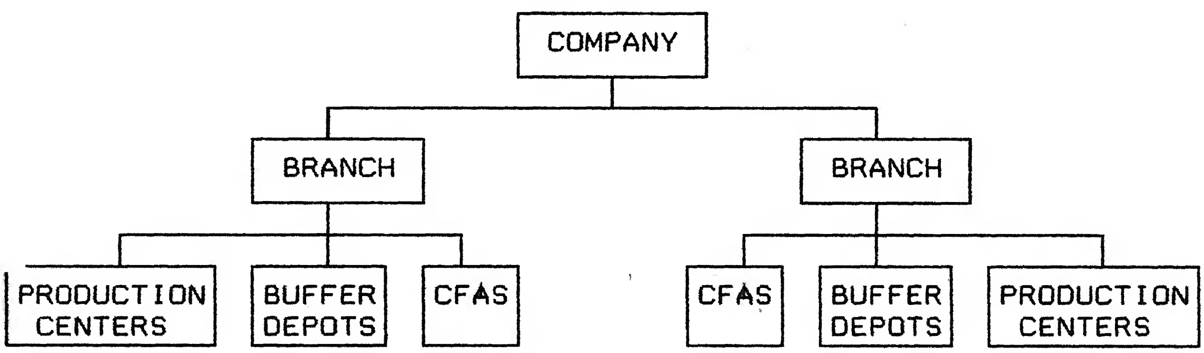

FIG. 1.4 Organisational Structure of DREAT CO.

The company's organization consists of regional branches, each branch supervising a specific region. Each branch has certain distribution centers known as carrying and forwarding

agencies (CFA) as shown in FIG. 1.4.

Further, the demand for Drink is seasonal and highly variable, while that of Eat is reasonably stable and should be satisfied at all costs. Since the production centers and CFAs have a fixed storage space, in certain periods it may not suffice to store the products. In order to make available additional space, the company hires certain warehouses.There is no restriction on the no. and capacity of warehouses a branch can have. Here, it is to be observed that the buffer in a branch caters to the CFAs within that branch only whilst the production center caters to the company as a whole.

The distribution of products to CFAs is done in truck loads. Though there is no restriction on type of truck to be considered, it is preferred to have only heavy commercial trucks for dispatches. Though vehicle routing is to be preferred, there should not be too many destinations on a certain route, as it will take considerable time to stop there. The company follows weekly distribution policy.

In nut-shell the characteristics of the DREAT CO. can be listed as :

* Consumer goods business.
* Multi product - multi production center.
* Perishable commodity.
* Nation-wide distribution network of CFA and warehouses.
* Stable demand for certain products & seasonal for others.

* Consumer demands are to be satisfied at any cost.
* Distribution using a mix of vehicles.
* Production centers may be restricted to produce a certain class of products.
* Production centers has a maximum production capacity for time period and minimum utilization requirement for the whole year.

The alternative plans for production and distribution have to be generated and evaluated using the following information :

1. Period wise demands of each product at each CFA for the horizon.
2. Fixed CFA and production center locations.
3. Production capacity at each production center.
4. Minimum utilization requirement to be met by each production center.
5. Range of products, the production center can produce.
6. Costs at production center, viz. production cost, setup cost,production rate change over cost,etc.
7. Inventory carrying costs at CFA, center and warehouses.
8. space availability at the CFA, center and warehouses.
9. Capacity of vehicles and their costs of transportation.
10. Potential warehouse location and cost of their setup.

DECISION FRAME WORK

The main aim of the study is to develop a **Decision Support System** which can assist in the following type of decisions for **Integrated Production Distribution Planning**:

1. The quantity of each product to be produced at each

production center for each period.

2. Sequence of products to be produced.
3. Allocation of various products for dispatch to various CFAs and intermediate warehouses from production centers and from warehouses to CFAs in each period.
4. Allocation of inventory to the space available at the production center, CFA and buffer.
5. Vehicle routing and dispatch scheduling.
6. The number and locations of warehouses to be located.
7. Allocation of CFAs to warehouses.

A framework for the evaluation of the alternatives for the above design is developed using following components :

1. Production cost.
2. Distribution cost.
3. Inventory holding cost.

MATHEMATICAL MODEL

Shyam [17] attempted to model the problem as a mathematical program. Mathematical programs which are powerful modeling tools for such problems have certain inherent limitations. From the formulation following points can be observed :

1. It is difficult to obtain a linear formulation with all these considerations.
2. The size of the problem consisting both linear and integer variables becomes too large.

Since solution procedures used in solving linear and

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DECISION FRAME WORK

The main aim of the study is to develop a **Decision Support System** which can assist in the following type of decisions for **Integrated Production Distribution Planning**:

1. The quantity of each product to be produced at each

CHAPTER - 2

PROBLEM DECOMPOSITION

The prime motivation behind the work is to develop a **DECISION SUPPORT SYSTEM** for the **INTEGRATED PRODUCTION-DISTRIBUTION PLANNING** that can be implemented in the micro computing environment. As discussed earlier the large mathematical structure is difficult to implement, hence the decomposition into more manageable structure is required during system design.

2.1 PROBLEM DECOMPOSITION

Since the size of ,the problem is roughly in multiples of time periods, as the time periods increases there is phenomenal increase in the problem size. Keeping this in view the problem is broken into subproblems each on the basis of time period and over-all time horizon is used as and when required. Such a strategy is likely to result in sub-optimal solution. However, in practice the demand itself is difficult to assess and is highly probabilistic in nature, hence the concept of optimal solution itself is not well identified.

The problem is decomposed into smaller sub problems using the scheme of decomposition developed in *Shyam* [17]. However, we improve various modules and incorporate a Decision Support System framework on the modules. The scheme can be described as solving a sequence of following major subproblems :

1. allocation of CFA demand to production centers.

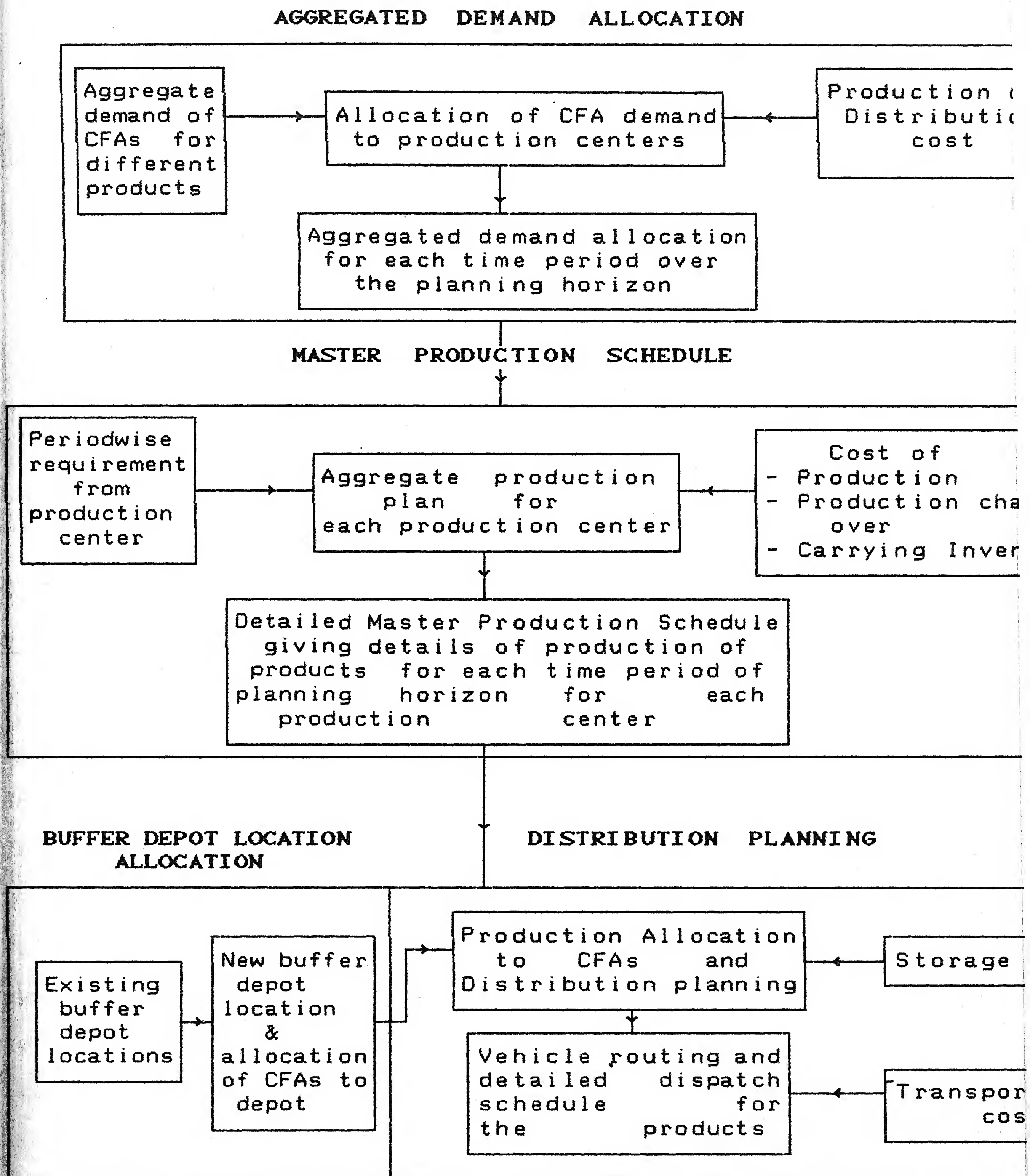


FIG 2.1 LINKAGE AMONGST VARIOUS SUB PROBLEMS IN INTEGRATED PRODUCTION DISTRIBUTION PLANNING.

1. allocation of CFA demand to production centers.
2. Period wise break up of demand allocation.
3. Aggregate production planning.
4. Master production schedule.
5. Production allocation to CFAs.
6. Distribution planning.
7. Buffer depot location allocation.

The sub-problems are linked to provide the system for IPDP. The linkage amongst the sub-problems is shown in fig 2.1.

In the following sections the sub - problems are dealt in detail.

2.2 DEMAND ALLOCATION

2.2.1 CFA DEMAND ALLOCATION TO THE PRODUCTION CENTERS

The production planning consists of developing the production plan for each production center, hence this can be decomposed into production planning for each center. Development of any such plan requires the projection of demand profile of CFAs to be supplied by the production center. Here a production center may be able to produce all or a few product types. The aggregate production capacity of all the production centers is sufficient to meet the aggregate demand of all the CFAs. Further each production center is required to produce at least the minimum production guarantee in the planning horizon.

The demand of various products for a CFA can be met by any of these production centers. However, it is preferred that supplies be made either from a single production center or if

infeasible, from small number of production centers. Allocation of CFA demand to production centers is also likely to affect the production as well as transportation cost. Hence the allocation of CFA demand to the production centers will be governed by the following considerations :

I A CFA may be supplied from as few production centers as possible.

II A production center may be allocated as few products as possible.

III Production and transportation costs be kept at a minimum.

We follow the demand allocation process as shown in *Shyam* [17]. However the MILP AGGALLOC in *Shyam* [17] has to be modified as there is an error in the formulated MILP.

MATHEMATICAL PROGRAM

ASSUMPTIONS :

a) There is minimum production level and maximum production capacity over the planning horizon for each production center.

b) Since the products differ basically in packaging and flavours, the variable cost of the product is function of only production and independent of product.

c) The transportation cost is function of the quantity supplied.

NOTATIONS :

Let

P : Number of production centers.

N : Number of CFAs.

K : Number of products.

T : Number of time periods in planning horizon.

M : A large constant.

D_{jk} : Requirement of product k for CFA j.

U_i : Upper limit on the production at production center i.

L_i : Lower limit on the production at production center i.

C_{ij} : Cost of production at center i and transportation to CFA j for one unit.

T_{ij} : Penalty for supplying CFA j from production center i. [fixed cost].

S_{ik} : Penalty for producing product k at a production center i. [fixed cost]

W_{ijk}: Allocated quantity of product k for CFA j to production center i.

$$Z_{ij} \begin{cases} 1 & \text{If CFA } j \text{ is allocated to production center } i, \\ 0 & \text{Otherwise.} \end{cases}$$

$$A_{ik} \begin{cases} 1 & \text{If product } k \text{ is produced at production center } i, \\ 0 & \text{Otherwise.} \end{cases}$$

MILP AGGPALLOC

$$\text{MIN} \quad \sum_i \sum_j C_{ij} \sum_k W_{ijk} + \sum_i \sum_j T_{ij} Z_{ij} + \sum_i \sum_k S_{ik} A_{ik} \qquad (2.1)$$

Subject to

$$\sum_i W_{ijk} = D_{jk} \qquad \forall \; (j, k) \qquad (2.2)$$

$$Z_{ij} \geq \frac{\sum_k W_{ijk}}{M} \qquad \forall \; (i, j) \qquad (2.3)$$

$$A_{ik} \geq \frac{\sum_j W_{ijk}}{M} \qquad \forall \; (i, k) \qquad (2.4)$$

$$L_i \leq \sum_j \sum_k W_{ijk} \leq U_i \qquad \forall \; (i) \qquad (2.5)$$

$$Z_{ij}, A_{ik} \in (0, 1). \qquad (2.6)$$

Equation (2.2) indicates that the demand of the ducts at CFAs is met by the allocated quantities to the duction centers.

Inequalities (2.3) and (2.4) are to enforce (0, 1) iables.

Inequality (2.5) maintains the allocation to each duction center within it's minimum guarantee and production acity.

Here, the total number of integer & linear variables the constraints are(P*K + P*N), (P*N*K) and (P*(1+K)+ K*N +) respectively.

Even for a problem of 4 production centers, with 4 type products and catering to 50 CFAs the number of linear iables, integer variables and constraints turns out to be

800,216 and 420 respectively, which is fairly small and can be solved in reasonable time.

For the large size problems, the MILP AGGPALLOC may be decomposed into two comparatively smaller subproblems. First subproblem allocates the CFAs to the production centers and in the next the decision regarding products to be produced at the production centers can be made.

MILP AGGPALLOC1

$$\text{MIN} \quad \sum_{i}\sum_{j} C_{ij} V_{ij} + \sum_{i}\sum_{j} T_{ij} Z_{ij} \tag{2.7}$$

Subject to

$$\sum_{i} V_{ij} = \sum_{k} D_{jk} \qquad \forall \quad (\; j \;) \tag{2.8}$$

$$Z_{ij} \geq \frac{V_{ij}}{M} \qquad \forall \quad (\; i, j \;) \tag{2.9}$$

$$L_{i} \leq \sum_{j} V_{ij} \leq U_{i} \qquad \forall \quad (\; i \;) \tag{2.10}$$

$$Z_{ij} \in (0, 1). \tag{2.11}$$

Here V_{ij} is aggregated allocation of demand of CFA j to production center i.

FOr this problem total number of integer & linear variables and the constraints are (P*N), (P*N) and (P+N+P*N) respectively.

MILP AGGPALLOC2

$$\text{MIN} \quad \sum_{i}\sum_{k} S_{ik}A_{ik} \tag{2.12}$$

Subject to

$$\sum_{i} W_{ijk} = D_{jk} \qquad \forall \quad (j, k) \tag{2.13}$$

$$\sum_{k} W_{ijk} = V_{ij} \qquad \forall \quad (i, j) \tag{2.14}$$

$$A_{ik} \geq \frac{\sum_{j} W_{ijk}}{M} \qquad \forall \quad (i, k) \tag{2.15}$$

$$A_{ik} \in (0, 1). \tag{2.16}$$

In this problem total number of integer & linear variables and the constraints are (P*K), (P*N*K) and (P*K+ K*N + P*N) respectively.

2.2.2 TIME PERIOD WISE DISAGGREGATION OF ALLOCATION

The overall quantities of products allocated to each production center for each CFA W_{ijk} have been computed in the previous section. To develop the production plan for a production center, i.e. the quantity of each product to be produced in each period, we require the disaggregation of the total demand allocation to production centers for the CFAs, for each planning period. In this section we shall describe such a disaggregation method.

The disaggregation requires that for each time period (t) the requirement of each product k at each CFA j, which will

be met by production center i, O_{ijkt} be computed.

Due to large number of periods in planning horizon the number of such variables become large to be handled by a LP package on PC-AT. However, this can be achieved by solving a sequence of LPs for each time period, where the constraints of LP for a period are obtained from the one solved just before.

Shyam [17] has described such a process with LP DISAGG. However we improve it. LP DISAGG follows allocation of the period wise demand starting with first period. While our method LP PRDALLOC will work backward.

NOTATIONS

Let

$O_{ijk[t]}$ Allocation of requirement of CFA j to production center i, for product k, [in period t].

$D_{jk[t]}$ Demand of product k at CFA j [in period t].

$C_{i[t]}$ Capacity of production center [for period t].

U_i Average capacity of production center .

$P_{ij[t]}$ Production and transportation cost per unit from production center i to CFA j [for period t].

$L_{i[t]}$ Penalty for non production allocated at production center i [for period t].

$W_{ijk[t]}$ Total unallocated production for CFA j from production center i for product k [in period t].

$N_{i[t]}$ Allocated demand of all products which will be produc at production center i in previous periods due capacity constraint [after period t].

MILP PRDALLOC

$$\text{MIN} \quad \sum_i \sum_j P_{ij[t]} \sum_k O_{ijk[t]} + \sum_i \sum_k L\, N_{i[t]} \tag{2.14}$$

SUBJECT TO

$$O_{ijk[t]} \leq W_{ijk[t]} \quad \forall \quad (i,j,k) \tag{2.15}$$

$$\sum_i O_{ijk[t]} = D_{jk[t]} \quad \forall.. \quad (j,k) \tag{2.16}$$

$$\sum_j \sum_k O_{ijk[t]} - N_{i[t]} \leq C_{i[t]} \quad \forall \quad (i) \tag{2.17}$$

Since a LP is solved for each period, there are only (P*N*k) + (N*K) decision variables in a specific period.

Starting from last period we go down to first one.

Then for previous period

$$W_{ijk[t-1]} = W_{ijk[t]} - O_{[ijk[t]]}; \tag{2.18}$$

and

$$C_{i[t-1]} = U_i - N_{i[t]} ; \tag{2.19}$$

And for last period

$$W_{ijk[T]} = W_{ijk} \quad \text{and} \tag{2.20}$$

$$C_{i[T]} = U_i ; \tag{2.21}$$

2.3 PRODUCTION PLANNING

We follow the same scheme developed by *Shyam* [17]. The purpose of the production planning is to identify for each production center quantity of each product to be produced in each period. Any such plan will try to balance the production cost

consisting of production rate change over cost, product change over cost, with cost of carrying inventory.

To carry out the production planning, first we have to develop a demand allocation profile for each production center. This can be achieved by just summing up the demand of CFAs allocated to production center for each period.

2.3.1 AGGREGATE PRODUCTION PLANNING FOR PRODUCTION CENTERS

In aggregate production plan we shall obtain total production of all the products in each time period for a production center. In the aggregate production plan, as we are not decomposing the plan product wise, we will not consider product change over cost. Thus costs considered will be production rate change over cost and the inventory holding cost.

Such a plan will be prepared individually for each production center. The cumulative requirement from each production center for all products is determined for each period using PRDALLOC.

As shown in Fig. 2.2 a large number of feasible plans can be constructed by mixing up first two plans. The selection of the optimal plan can be done by using Dynamic Programming.

Here,

Plan 1 is a constant rate production plan,

Plan 2 is a minimum inventory plan and

Plan 3 is a plan with a production rate change in two periods.

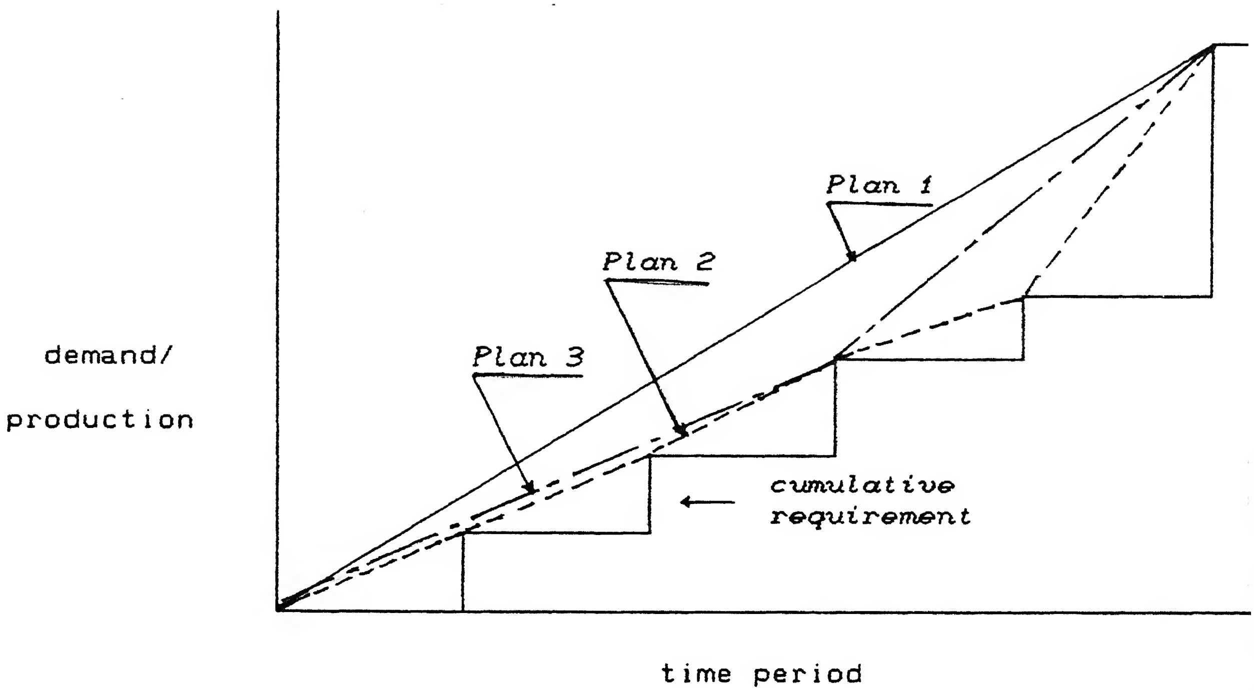


Fig 2.2 Profiles of Production Plans

DYNAMIC PROGRAMMING

DP AGGPROD

NOTATIONS

X_t Production in the period t.

f_{ij} Cost of production plan such that production rate between period j and i is constant (j < i) and optimal production plan is used up to period j.

Z^1_{ij} Inventory carrying cost between period j and i with constant rate of production.

Z^2_{ij} Cost of production from period j to i.

Z^3_{ij} Production rate change over cost due to difference in production rate of period j and (j - 1).

I_t Cost of holding one unit in period t.

C_t Cost of producing one unit in period t.

C Cost of change in production level of one unit.

Then if $f_i^*(X_i)$ denote the optimal production plan with production X_i in period i then,

$$f_i^*(X_i) = \underset{j=1,2..i-1}{\text{MIN}} \left[f_j^*(X_j) + Z_{ij}^1 + Z_{ij}^2 + Z_{ij}^3 \right] \qquad (2.22)$$

The costs Z_{ij}^1, Z_{ij}^2 and Z_{ij}^3 can be computed as follows :

Let the rate of production between period j and i be X and D_t be the requirement in period t.

Then

$$X = \frac{\sum_{t=j}^{i} D_t}{(i-j)} \qquad (2.23)$$

here $j < t \leq i$

and $X_t = X$.

The inventory at the end of period t be given as

$$(t-j)* X - \sum_{q=j}^{t} D_q \qquad (2.24)$$

Total Inventory carrying cost over period j to i

$$Z_{ij}^1 = \sum_{t=j}^{i} \left[\left(t - j \right) * X - \sum_{q=j}^{t} D_q \right] * I_t \quad ... \qquad (2.25)$$

and

$$Z^{2}_{ij} = \sum_{t=j}^{i} C_t \; X_t \qquad \ldots \qquad (2.26)$$

and the last one

$$Z^{3}_{ij} = C \mid X_{j-1} - X_j \mid \qquad \ldots \qquad (2.27)$$

Then

$$f^{*}_{i}(X_i) = \underset{j=1,2..i-1}{\mathrm{MIN}} \Bigg[f^{*}_{j}(X_j) + \sum_{t=j}^{i} \Big[\Big(t - j \Big) * X - \sum_{q=j}^{t} D_q \Big] * I_t$$

$$+ \sum_{t=j}^{i} C_t \; X_t + C \mid X_{j+1} - X_j \mid \Bigg] \qquad (2.28)$$

The production plan will be given as $(X_1, X_2, \ldots X_T)$.,

2.3.2 MASTER PRODUCTION SCHEDULE (PRODUCT WISE PRODUCTION PLAN)

The aggregate production plan is further required to be disaggregated product wise. The disaggregation is required to meet the periodic demand allocated to the production center with minimum product change over cost. This is likely to result in lower production costs due to less product change over. This is achieved through following MILP developed by *Shyam [17]*.

NOTATIONS :

$R_{[i]kt}$ Quantity of product k produced in time period t from production center i.

X_t Total production (as per production plan) in period t.

$Y_{[i]kj}$ Total allocated demand of product k in period j (obtained from the demand disaggregation).

$$Y_{[i]kt} = \sum_{J} Q_{[i]jkt}$$

$$A_{[i]kt} \begin{cases} 1 & \text{If product k is produced at production center i,} \\ 0 & \text{Other wise.} \end{cases}$$

C_{kt} Set up cost for product k in period t.

M A large constant.

$$\text{MIN} \quad \sum_{k} \sum_{t} C_{kt} A_{[i]kt} \qquad (2.29)$$

Subject To

$$\sum_{k} R_{[i]kt} = X_t \qquad \forall \ (\ t \ ) \qquad (2.30)$$

$$\sum_{j=1}^{t} R_{[i]kj} \geq \sum_{j=1}^{t} Y_{kj} \qquad \forall \ (\ k, \ t \ ) \qquad (2.31)$$

$$A_{[i]kt} \geq \frac{Q_{[i]kt}}{M} \qquad \forall \ (\ k, \ t \ ) \qquad (2.32)$$

$$A_{[i]kt} \in (\ 0, \ 1) \qquad (2.33)$$

Equation (2.30) ensures that total production is same as obtained from production Plan.

Inequality (2.31) ensures that production is sufficient to meet the requirement.

Inequality (2.32) is included to enforce the binary variables.

Alternatively if the MILP takes too much time, due to

number of periods then heuristic method can be used. We developed the heuristic DISEG_PROD for this purpose. However, it does not guarantee optimal solution.

The product wise demand allocated to the center is determined by summing up allocation over the CFAs. The inventory is subtracted from allocation to find out the requirement of products which will be met by producing in the period. After finding out the quantities of products required to be produced in the period, it is checked whether additional production is to be made to match the production rate. Here we select the minimum among the products (which are being produced in the period) allocated to the center in the coming periods. Selection of minimum is likely to provide more flexibility in plan and will attempt to keep the product change over at minimum.

NOTATIONS :

I_k Inventory of product k.

P_{kt} Production of product k in period t.

R_{kt} Requirement of product k in period t in addition to inventory of product k.

D_{kt} Requirement of product k in period t.

E_t Production rate in addition to requirement in period t.

HEURISTIC DISEG_PROD

1. $t := 0;$

   $I_k := 0; \quad \forall \ (\ k \ )$

2. inc(t); if $t > T$ stop.

   For periods $i \le t$

   for all products k $R_{ki} = D_{ki};$

3. For periods $i \geq t$

for each product k.

Begin

$R_{ki} = R_{ki} - I_k;$

$I_k = I_k - R_{ki};$

If $R_{ki} < 0$ $R_{ki} := 0$ else $I_k := 0;$

End;

4. For all products k

$P_{kt} = R_{kt};$

5. Excess production $E_t := X_t - \sum_k P_{kt};$

PROD_SET := [Product being produced in period t];

If $E_t = 0$ goto step 12;

If $E_t < 0$ goto step 8;

6. Find period $(i>t)$ and product k being in PROD_SET in which $(R_{ki} > 0)$ and $(R_{k(i-1)} = 0)$and requirement R_{ki} is minimum among all such products.

7. temp := MIN $\{ E_t, R_{ki} \}$

$E_t := E_t - \text{temp};$

$P_{kt} := P_{kt} + \text{temp};$

$R_{ki} := R_{ki} - \text{temp};$

If $E_t > 0$ goto step 6 else goto 12;

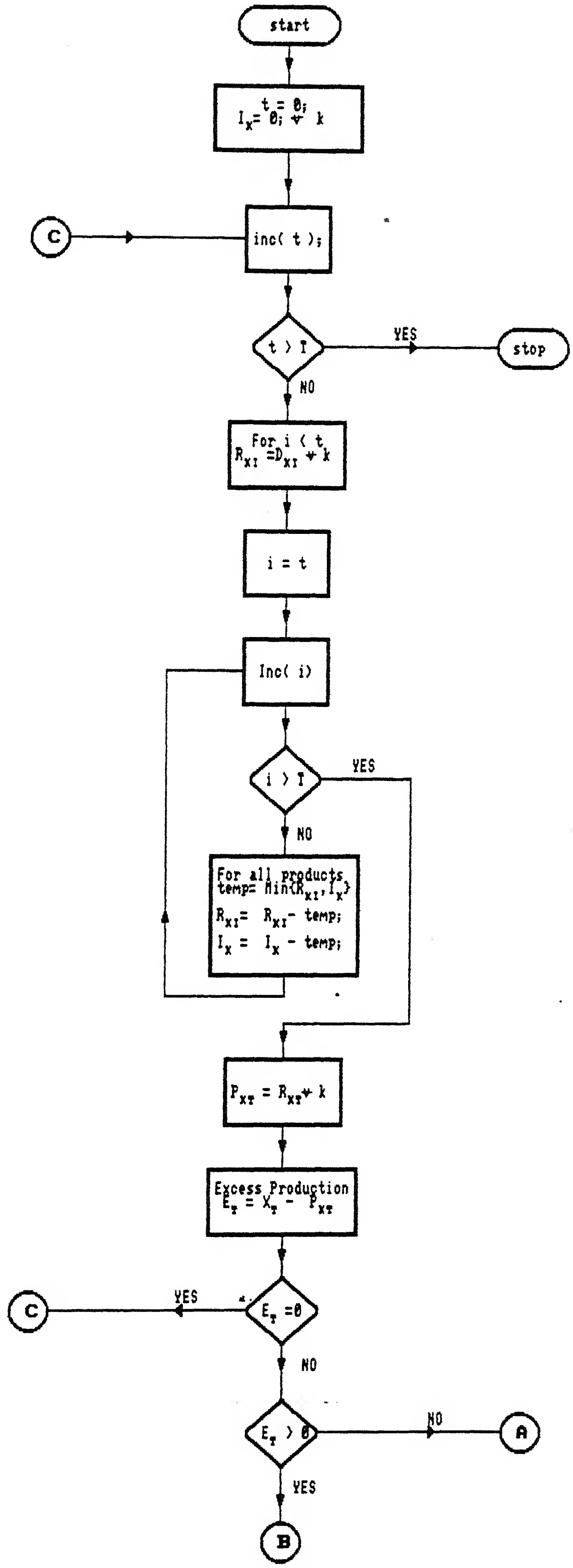
8. Find product k such that $I_k > 0;$

Find product j such that $R_{jt} > 0;$

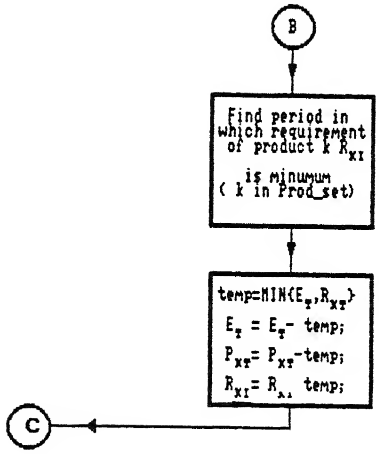
9. i := t;

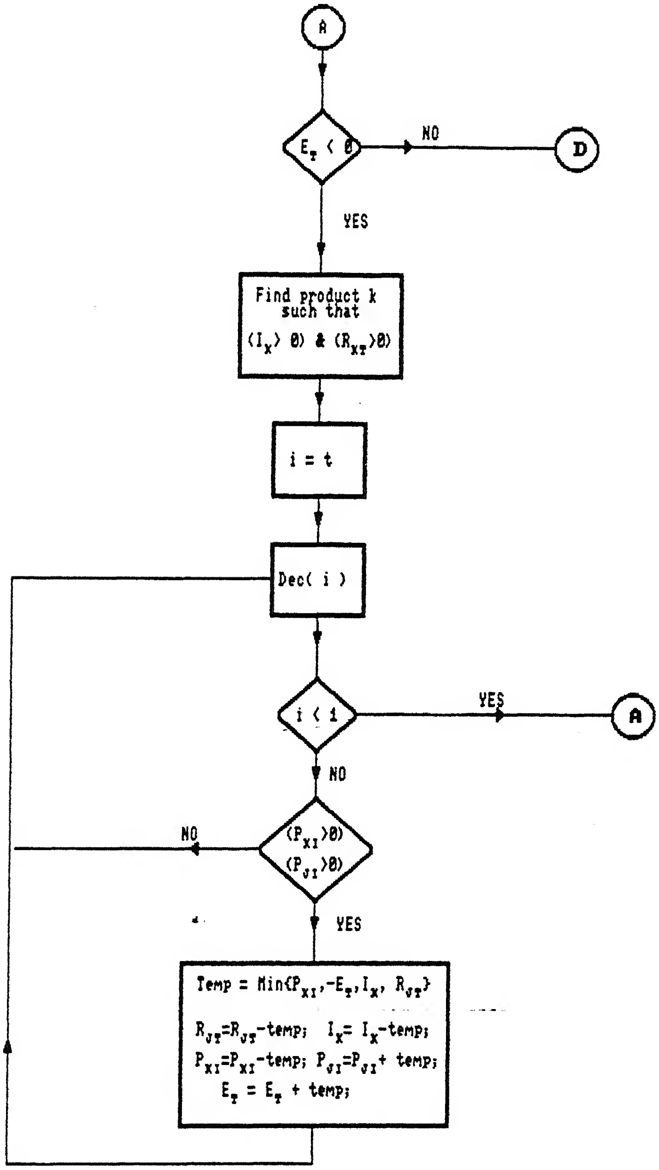
10 dec(i); If (i < 1) goto 8;

11. If $(P_{ki} > 0)$ and $(P_{ji} > 0)$



start
t = 0;
I_x = 0; ∀ k
inc(t);
t > T
YES
stop
NO
For i < t
R_xi = D_xi ∀ k
i = t
Inc(i)
i > T
YES
NO
For all products
temp= Min{R_xi, I_x}
R_xi = R_xi - temp;
I_x = I_x - temp;
P_xT = R_xT ∀ k
Excess Production
E_T = X_T - P_xT
E_T = 0
YES
C
NO
E_T > 0
NO
A
YES
B
C


B
Find period in which requirement of product k R_XI is minumum (k in Prod_set)
temp=MIN{E_I,R_XI}
E_I = E_I- temp;
P_XI= P_XI-temp;
R_XI= R_XI- temp;
C


A
E_I < 0
NO
D
YES
Find product k such that (I_X> 0) & (R_XI>0)
i = t
Dec(i)
i < 1
YES
A
NO
(P_XI>0)
(P_JI>0)
NO
YES
Temp = Min{P_XI,-E_I,I_X, R_JI}
R_JI=R_JI-temp; I_X= I_X-temp;
P_XI=P_XI-temp; P_JI=P_JI+ temp;
E_I = E_I + temp;

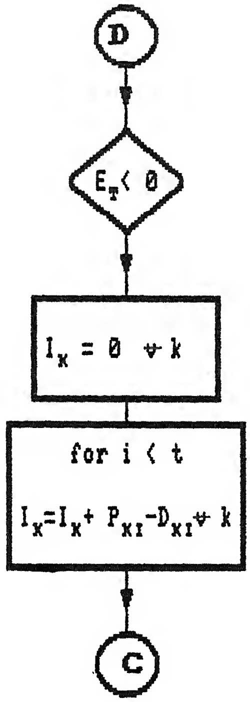


FIG 2.3 PRODUCT WISE DISAGGREGATION OF PRODUCTION

Begin

$$temp := MIN \left\{ P_{ki},\ (-E_t),\ I_k, R_{jt} \right\};$$

$R_{jt} = R_{jt} -$ temp;

$I_k = I_k -$ temp;

$P_{ki} = P_{ki} -$ temp;

$P_{ji} = P_{ji} +$ temp;

$E_t = E_t +$ temp;

End;

If $E_t < 0$ goto step 10;

12. $I_k = 0$;

for period $i \leq t$

for products k

$I_k = I_k + P_{ki} - D_{ki}$;

goto step 2.

2.3.3 PRODUCTION ALLOCATION TO CFA

The aggregate product wise production plan for each production center was obtained at previous stage. Now this production should be allocated to the CFAs such that the requirement profile developed at the period wise disaggregation stage of demand allocation (in sec 2.3) can be met.

It is to be observed that the allocation of the CFA has an impact on the distribution plan as it affects the quantum of dispatch. Thus it is desirable to allocate the production to CFAs in bulk. This is accomplished by solving the following MIIP which is developed by *Shyam* [17], for each production center.

NOTATION :

$R_{[i]kt}$ The quantity of product k produced in time period t at center i.

$O_{[i]jkt}$ Allocated demand of product k at CFA j to production center i in period t.

$F_{[i]jkt}$ Cost of allocating unit of product k to CFA j in period t from center i.

$C_{[i]jt}$ Cost of allocating the products to CFA j in period t.

M A large number.

DECISION VARIABLES :

$P_{[i]jkt}$ Quantity of product k produced at center i in period allocated to CFA j.

$$Z_{[i]jt} \begin{cases} 1 & \text{If CFA } j \text{ is allocated to production center } i \text{ in period } t. \\ 0 & \text{Otherwise.} \end{cases}$$

MILP PRODALLOC

$$\text{MIN} \quad \sum_{j}\sum_{t} C_{[i]jt} Z_{[i]jt} + \sum_{j}\sum_{k}\sum_{t} f_{[i]jkt} P'_{[i]jkt} \qquad (2.34)$$

Subject To

$$\sum_{j} P_{[i]jkt} = R_{[i]kt} \qquad \forall \quad (k, t) \qquad (2.35)$$

$$\sum_{q=1}^{t} P_{[i]jkq} \geq \sum_{q=1}^{t} O_{[i]jkq} \qquad \forall \quad (j, k, t) \qquad (2.36)$$

$$Z_{[i]jt} \geq \frac{\sum_{k} P_{[i]jkt}}{M} \qquad \forall \quad (j, t) \qquad (2.37)$$

$$Z_{[i]jt} \in (0, 1) \qquad (2.38)$$

The equality (2.35) balances the allocation with production.

The inequality (2.36) maintains that requirement in each period is met.

Inequality (2.37) is introduced to enforce the binary numbers for $Z_{[i]jt}$.

For each problem, total number of (0,1) variables is equal to the number of CFAs being served by production center multiplied by the number of time periods (P*N). If problem size becomes large the sequence of LPs can be solved after eliminating constraint (3) and setting $C_{[i]jt} = 0$ to make it smaller.

2.4 DISTRIBUTION PLANNING

While doing distribution planning, following considerations are to be dealt with :

* Buffer depot location allocation.
* Allocation of inventories to CFAs, production centers and buffer depots.
* Scheduling and routing of vehicles to ship the production to CFAs and buffer depots from production center and to CFAs from buffer depots.

Since the last two considerations depends upon the first one, the buffer depot location allocation is required to be made earlier. And then the allocation of inventory and at last the vehicle routing will be done.

2.4.1 BUFFER DEPOT LOCATION ALLOCATION

The major costs which govern the location and allocation of buffer depots are the setup cost and transportation cost of allocated inventories to CFAs and buffer depots. Each CFA requires buffer depot due to either storage or distribution considerations.

Here it should be noted that the quantity to be shipped to the buffer depot or supplied to the CFA from buffer depot and storage space required for a CFA at any buffer depot are dependent on distribution planning which in turn is dependent of buffer depot location and allocation.

Since the storage and distribution of goods via buffer depot incurs additional costs, it is preferred to store them at center or CFA as long as space is available. And the buffer depots are assumed to be incapacitated. Thus the space required at buffer depot is nothing else than sum of quantities which can not be stored at production center and CFA and is to be delivered to the CFA allocated to buffer.

The location allocation problem is solved by following MILP LOCALLOC developed by *Shyam* [17].

NOTATIONS :

C_{jb} Penalty of allocating CFA j to warehouse b.

F_b Setup cost of warehouse b.

M A large number.

DECISION VARIABLES :

$$Y_b \begin{cases} 1 & \text{Warehouse is open at location b,} \\ 0 & \text{Otherwise.} \end{cases}$$

$$A_{bj} \begin{cases} 1 & \text{CFA j is allocated to warehouse b,} \\ 0 & \text{Otherwise.} \end{cases}$$

MILP LOCALLOC :

$$\text{MIN} \quad \sum_{j} \sum_{t} C_{jb} \, A_{jb} + \sum_{b} F_b \, Y_b \qquad (2.37)$$

Subject To

$$\sum_{j} A_{jb} = 1 \qquad \forall \; (\; j \;) \qquad (2.38)$$

$$Y_b \geq \frac{\sum_{j} A_{jb}}{M} \qquad \forall \; (\; b \;) \qquad (2.39)$$

$$Z_{jb}, Y_b \in (0, 1)$$

Since the buffer depot can be allocated to only those CFAs within the branch, in it is located. However due to probabilistic nature of the forecasted demand, there is no guarantee that space at the buffer depot will match with actual requirements. In such cases the balance of space will have to be located for short term.

2.4.2 INVENTORY ALLOCATION

Once the warehouse location allocation and the production has been considered, the allocation of inventory and it's dispatch to CFAs and warehouse should follow.

We can either plan the quantity to be shipped and then identify the routes or can do it other way round. Actually the routes operate on road networks, where vehicle has to go via some locations to reach destinations. The destinations are the CFAs and warehouses. Considering the fact that CFAs and warehouses, likely to be served by a vehicle are clustered, the vehicle routing aspect will be preceded by inventory allocation.

Due to the space availability at the production centers, CFAs and warehouses, there are options available for the allocation of the inventory. Taking all this into consideration, we shall determine the quantity to be dispatched. Keeping in view the stop time and perishable nature of products, the number of destinations for a vehicle has to be restricted.

The requirement at a CFA, in any period is met either from the stock at CFA or dispatch from production center or warehouse, If the quantity is for future use, then it is stored at production center or at CFA or at warehouse in order. The rationale behind this is that if it is stored at the production center, then there is no immediate transportation and storage cost and considered for optimal dispatch in future periods. And dispatch to CFA preferred over warehouse due to less storage cost and saving of additional transportation.

There is a time lag between the delivery to the buffer depot and the dispatch from the buffer depot, by which time it is assumed that sufficient space is available at the CFA to hold the current requirement, which is stored at the buffer depot.

2.4.3 VEHICLE ROUTING

The vehicle routing is carried out in two phases :

1. Vehicle routing from the production center.
2. Vehicle routing from the warehouse.

The vehicle routing is done for each source and for each time period. First the destinations with dispatch more then truck load are taken and full truck loads are scheduled for them. The remaining quantities are clustered by the heuristic VEH_ROUTING given here.

The number of vehicles needed is found, and destinations with requirements of more than one truck. From the remaining destinations we find out the destinations with highest demand and saving in transportation by clubbing it with the destinations in the vehicle route are determined. It is assigned to the vehicle, in which it is likely to result in maximum saving of transportation.

NOTATIONS :

VEH_NO Number of vehicles required to dispatch the production to destinations.

VEH_CAP Capacity of vehicle in terms of product units.

SEED_ROUTE A set of destinations last visited on routes.

HEURISTIC VEH_ROUTING :

1. Number of vehicles required

$$\text{VEH\_NO} := \text{MAX}\left\{\text{Destination with demand} > 0.5\ \text{VEH\_CAP},\ \text{TRUNC}\left(\text{Total demand/VEH\_CAP}\right) + 1\right\};$$

2. $\text{SEED\_ROUTE} := \left[\text{Destinations with demand} > 0.5\ \text{VEH\_CAP}\right]$

   If vehicles remain add destination with highest demand in SEED_ROUTE;

3. Find cost of conducting separate trip to destinations not in SEED_ROUTE (or distance from source) ;

4. Take destination $j \notin$ SEED_ROUTE

   (a) Find saving in cost(or distance) by including it into route with SEED.

   (b) Check VEH_CAP;

5. Club the destination with trip resulting in maximum saving. Update SEED_ROUTE; If destinations remain to be routed then goto step 4.

CHAPTER 3

SYSTEM DESIGN
AND
IMPLEMENTATION

The objective of present work is to design and implement a Decision Support System framework for the different modules of Integrated Production-Distribution Planning (IPDP) in micro computing environment.

Decision support system represents a point of view on the role of computers in the managerial decision making. The decision support system implies the use of computers to :

1. Assist managers in their decision making process in the semi structured problems.
2. Support, rather than replace managerial decision making.
3. Improve the effectiveness of decision making rather then it's efficiency.

The system should be designed taking into consideration the computing costs, resources available and it should be user friendly.

3.1 SYSTEM DESIGN

A DSS design will require identification of the following :

* Information needed by system.
* Strategic information for decision making.
* Selection of the system components.

* Output generation.
* System organisation

3.1.1 INFORMATION NEEDED BY SYSTEM

The identification of the required information for effective decision making and matching it with the available information is an important aspect of the system design for DSS. For the integrated production distribution planning (IPDP) of a hypothetical company DREAT corporation, the decision framework is based on the following information :

a) Demand profile of CFAs

The product wise demand of all the CFAs for each time period should be available apriori. In practice a forecasting system has to be used to arrive at such demand profile. The time horizon for which profile is needed has to be compatible with the planning horizon. It is assumed that the demand is fairly predictable and uncertainty associated with the forecast is negligible.

b) Production center information

The minimum production guarantee for each production center over the planning horizon and the production capacity for each time period should be known. Also the range of products which can be produced at each production center should be available. This information will be generally available with fair degree of accuracy. Uncertainty in the production facility i.e. major breakdown, etc. are not taken into consideration.

c) **Distance data**

Since the CFA allocation to centers, warehouse location allocation and distribution planning are to be governed by the distance between CFA, center and warehouses, the distances between CFA and centers, inter CFA and between CFA and warehouse are needed. This information will be generally available with fair degree of accuracy. In case, the transportation cost is directly available, this information will be redundant. Generally all distances will be considered for road transport by using roads which are commonly used for such transport.

d) **Potential warehouse locations**

The sites, where the warehouses are either already located or can be located have to be identified. This information will generally be available with fair degree of accuracy.

e) **Space considerations**

The storage space availability at the production center, CFA and space each product could occupy should be available. Generally this information will be available with reasonable certainty. However additional availability of space especially at the warehouse may vary as it can be ascertained with certainty only after a decision to establish a warehouse has been taken.

f) **Vehicle capacity**

The capacity of vehicle in terms of product units should be available. This can be estimated fairly accurately.

3.1.2 STRATEGIC INFORMATION

The system designed should provide right kind of information at the right time to the decision maker to take the effective decisions. The decisions, which need subjective evaluation should be carried out by decision maker and rest be made by processing the information. The following strategic information will be required to evaluate alternatives for decision making :

1. Production cost

In general production cost will have following three components :

a) For each production center and for each product the actual cost of production which includes material, labour, overheads, etc. Such cost of production can be a function of production volume.The DSS will permit this cost to be specified as :

(i) Cost per unit, uniform over whole product range.

(ii) Total production cost function for the range of production.

Generally some estimate of the cost are available in each organization. However,it has to be analysed more carefully especially to include those costs elements which differ with production volume and from production center to production center.

b) Production rate change over cost : Whenever a major change in production level takes place, certain additional costs may have to be incurred. It may be noted that production rate change over cost and production cost should be clearly separated out.

Only those components of costs which are affected by changes of production from one level to other should be included. This may include cost of hiring & firing labour, overtime payment, sub-contracting, etc.

c) Product change over cost : This cost may include estimate of downtime cost for product change over, cleaning cost (if any such costs are incurred) and set up cost (whenever changes in setup is required). The cost of wastage in the system, whenever such changes takes place should also be included.

2. Storage cost

The cost of carrying inventory at CFA, center and warehouse should be available. Inventory plays crucial role and good estimate of costs related with holding of inventory are a must for an effective system. Such cost should include financial charges for holding inventory , rental for space,cost for maintenance of stores, insurance charges and loss during storage, etc. Generally such estimates (other than financial charges) are difficult to be made. In such cases attempt should be made to identify the difference in inventory cost at various locations (plant, warehouse,CFA).

3. Transportation cost

The transportation cost per unit of product from various production centers to the warehouses and CFAs and from buffer depots to the CFAs should be available. It is assumed that all transportation is through road using trucks of various capacities. Cost for full truck with various capacities can be estimated. However, the cost of partial trucks are more difficult

to estimate. Generally cost of transportation per unit will be obtained by dividing the cost of full truck by number of units the truck can carry.

4. Warehouse setup cost

The fixed cost of opening a warehouse at a site should be available. This may include annualized cost of constructing such warehouses, cost of establishment required to operate the warehouse, etc.

3.1.3 SYSTEM COMPONENT SELECTION

One of the major components of the system is an LP/ILP solver. As solving a large LP/ILP is iterative process and requires considerable amount of computing time, it is decided to use one of the commercially available LP/ILP solvers.

Our need was a PC version of a software which can handle a considerable number of linear as well as integer variables and constraints. The latest PC version of HYPER LINDO (1989) allows 1999 rows, 3999 columns and 1000 integer variables and 16000 non-zeros. The package is considerably suitable for the intended purpose.

HYPER LINDO will use an 8087 chip for floating point calculations to improve speed and precision. Co-processor will be used to improve the solution time. The HYPER LINDO requires the input to be in a specified format.A LP formulator is developed and used to make the input files for HYPER LINDO.

3.1.4 OUTPUT GENERATION

The output contains following information either to be evaluated by user or to be provided by the system.

1. The overall allocation of the CFA demand to production centers.
2. The aggregate quantity to be produced at each production center in each period, i.e. Aggregate Production Plan.
3. The overall quantity of each period to be produced at each production center over the planning horizon, i.e. Master Production plan.
4. The location and allocation of the warehouses.
5. Inventory allocation to the production centers.
6. Dispatch schedule of trucks indicating the quantities of each product being dispatched to each CFA or warehouse from production center and to each CFA from warehouse.

3.1.5 SYSTEM ORGANIZATION

The objective of the IPDP is to provide support to decision making process and perform following three vital functions.

a) Demand allocation.

b) Production planning.

c) Distribution planning

   1) Warehouse location allocation and

   2) Inventory allocation and vehicle routing.

In the following sections the above mentioned functions of system are organized by providing the user interaction at

different stages. These interactions are described below :

(A) DEMAND ALLOCATION

This is carried out in two phases. At first the aggregated product wise demand of each CFA is allocated to the production centers. And in next one disaggregation over the planning horizon for each production center is carried out.

The allocation of CFA demand is governed by three factors (costs or penalties) :

(i) Production and transportation cost.

(Co-efficient C_{ij} in section 2.2)

The production cost is assumed to be same for all the CFAs to be supplied. Where as transportation cost will depend upon the CFA because of different distances between center and CFA. The system will provide flexibility to the user to specify the transportation cost in any of the following formats :

1. Function of distance between CFA and center.
2. specific cost of transportation between each CFA and center.
3. Total cost of transporting a vehicle between the CFA and a center.

These are converted into transportation cost per unit of product to be transported to CFA by the system.

(ii) Penalty of CFA allocation to center

(Co-efficient T_{ij} in section 2.2)

Penalty of CFA allocation to center is important requirement of the IPDP to identify the CFAs to be supplied by a

production center. Such a decision, in addition to the transportation cost can be based on the following considerations:

(1) Company practice due to the organizational reasons is to supply a CFA from only one production center.

(2) Company will prefer to supply a CFA a product from single source, but it is not a requirement.

(3) Regulatory reasons do not permit certain CFA to be supplied from certain production centers.

(4) Transportation time limits the supply of certain products from certain production centers to certain CFA.

All such considerations by the user can be taken care of, by the system by providing a penalty for allocating a CFA to a center. Such a function by imposing high or low values, can easily incorporate issue level 1, 3 and 4. These penalties can be specified in any of the following forms :

1. Function of distance between CFA and center.
2. Function of priority given to centers for each CFA by user.
3. Function of priority given to centers based upon the distance between them.

(iii) Product change over cost
(Co-efficient S_{ik} in section 2.2)

Product change over cost is incorporated in the model to reduce the number of product change over at the production center. This may be specified in any of the following format :

1. Function of product type.
2. Constant for the production center.
3. No cost. (if change over does not impose additional

cost for setup)

The feasibility of the problem is checked, whether the total demand is in between the sum of minimum production guarantee and sum of the production capacity of all production centers. If it violates any of these then either minimum production guarantee/production capacity of the centers, or the demand of CFAs need to be changed.

When the priorities are given as penalty, the scaling becomes necessary. The priorities are scaled to the order of production costs for the production center.

User can also pre assign CFA to be production center. This helps in reducing the problem size.

The user can control the coefficients T_{ij}, S_{ik} and C_{ij} to provide different weights to the objectives listed in section 2.2.1. User is asked if he want to give different weights to the objectives. The costs/penalties are proportionately changed. In fact following objectives can be enforced :

a) If allocation of small number of production centers to each CFA is desired, then set C = 0, T = constant and S_{ik}=0.

b) If minimization of transportation cost is desired then set T_{ij}= 0, S_{ik}= 0.

c) IF production of smaller number of products at each production center is of prime importance, then C = 0, T_{ij}= 0 and S_{ik}= constant.

The MILP is formulated with the data given to system and solved by using HYPER LINDO. The MILP to be solved by HYPER

LINDO is required to be in a specified format. By help of LP formulator this is obtained. The sensitivity analysis is also done for the optimal solution obtained for the MILP. The solution is processed to give a brief summary to the user. The demand of CFAs allocated to the centers are shown. Also the quantity of each product at the production centers is shown to user.

After first solution the user has option to modify a part of information to the system. If information is changed then system checks whether it will be affecting the solution. If it is likely to change the solution, the MILP is formulated again and solved. The repetitive use of this by user gives the idea to user that how these demands are allocated. The final solution will be stored as the product wise demand allocation of various CFAs to production centers. This is used for the period wise disaggregation of allocation of the CFA demand.

Here the MILP is formulated for each period and solved to give the period wise product wise allocation of CFA demand to production centers. The capacity up to a period should be sufficient to meet the demand up to that period. If not so then the production capacity will have to be increased.

(B) PRODUCTION PLANNING

The production planning process is carried out in three steps :

(i) AGGREGATE PRODUCTION PLANNING

The aggregate production planning is the identification of the total production during each period at the production

centers. The decision of production rate is governed mainly by the production cost, cost of carrying inventory and cost due to production rate change over.

The production cost may be specified as

1) Constant for a production center.

2) Dependent of production level in period.

The production rate change over cost may be specified as

1) No change over cost.

2) Constant (independent of the level of difference between the production level).

3) Dependent of previous and new production level i.e. it is function of the previous production rate and difference between previous and new production rate).

The cost of carrying inventory can be given as :

1) Constant (independent of level of inventory).

2) Linear function of the inventory level.

3) Step wise function of the inventory level(here the inventory is classified into certain classes. And inventory cost is constant for a class).

Once the cost figures are obtained the alternate plans are evaluated with respect to cost and the minimal cost plan is displayed. The number of alternatives is reduced by neglecting the plans in which the periodic demand in all periods is not met.

The user is provided facility to change the cost structure and rerun the DP as well as the modification in the production rate provided it does not violate the demand.

(ii) MASTER PRODUCTION SCHEDULE

The identification of the quantum of each product to be produced in each period is known as master production schedule. This decision is solely governed by the product change over cost and the total production is bounded by the production rate obtained in aggregate production plan. The production is disaggregated to meet the product wise demand of various product with least number of product changes over the planning horizon.

The cost of product change over may be specified as

(1) Independent of products. It means the total cost of change over is proportional to the total number of setups required over the planning horizon.

(2) Function of current product.

(3) Function of previous as well as current product.

Two solution methods for the problem are provided each having specific merits and demerits. The first one is by solving a series of MILPs for each production centers with minimization of total product change over cost objective. The other one is by a heuristic developed by us with objective of minimizing number of setups. The ILPs give optimal solution but needs large amount of times if the number of integer variables is large. Whereas heuristic may not be able to give optimal solution but is quite fast. User has the option to specify the method.

The solution obtained by both the methods may have small quantities of various products in some periods. This needs a subjective evaluation by the decision maker and he can modify

the quantity. The effects of these changes are shown to the user and if he agree these are updated. The rate of production may be different due to these changes but in any case demand should not be violated.

(iii) PRODUCTION ALLOCATION TO CFA

Once the decision of identification of quantum of various products to be produced have been done, the allocation of production to various CFAs is required to be made. Though the production allocation is not directly related to any cost, but in long run it affects the distribution planning. Thus the objective behind the production allocation is to meet the allocated demand in such a way that whenever some allocation is done it is in bulk.

The production allocation is done by solving a series of MILPs one for each production center, such that the number of times allocation is made to CFAs is least and demand of the CFAs is met.

(C) DISTRIBUTION PLANNING

Once the production rate and its allocation decisions are taken finally the warehouse allocation and inventory allocation & vehicle routing decisions are to be taken. This can be divided into three units :

(i) WAREHOUSE LOCATION-ALLOCATION

Here, the decisions regarding the location at which the warehouses are to be opened among the potential sites and CFAs which will be catered by the warehouse are made. The objective

is that each CFA should get supply from one and only one warehouse and the total cost of opening the warehouse and penalty of allocation of CFAs to warehouses should be at minimum.

Some of the warehouse may have been already setup then their setup cost will be zero. Also some CFAs may have been allocated apriori based upon the subjective judgment of user. Also the number of CFAs which may be allocated to a warehouse maybe restricted by user.

The decision location and allocation is taken by solving a ILP with evaluation criteria for various alternatives of setup cost and allocation penalty. The penalty of CFAs allocation to the warehouse may be given in two forms :

(i) Function of distance between CFA and warehouse.

(ii) Function of priority to warehouses for CFA by user.

The distance of priorities provided to system are scaled such that they are in order of setup cost.

User may change the setup cost and allocation penalty and and their effects on the warehouse location and allocation. And finally, the best one found may be treated for further distribution planning.

(ii) INVENTORY ALLOCATION AND VEHICLE ROUTING

The vehicle routing decisions are preceded by the inventory allocation, to know the quantum to be shipped to the CFA or warehouse. Since the routing decisions generally required to be taken for coming period, the options are peovided to plan

the distribution for a period or over the planning horizon.

The inventory allocation is to be made after giving due consideration to the space available at the production center and CFA. Whenever the sufficient space is not available at the CFA and center the inventory is diverted to warehouse which are assumed to have enough space.

The allocated production of the current period is required to reach the CFA in current period if space is available at CFA then it is directly shipped, else directed to warehouse and the to CFA during that period. It is assumed that the space will be available at CFA by that time. If allocated production is for future periods then it is preferred to store at the production center. If space limitation forces us to ship it then we check whether space is available at CFA. If so, we ship it there else direct to warehouse.

Once the inventory allocated to the CFA, production center, and warehouse the last consideration comes into picture is how it should be routed. The full truck loads are always preferred over the partial one. So if the destination needs to be shipped the quantity more or equal to the truck capacity, it will be advisable to send a full truck. In case full trucks are not possible some destination are clubbed together to make it bulky. If some destinations are not desired to be clubbed together, a large transportation cost may be assigned to the route. Also as the number of destinations on a route increases the stop time becomes larger, thus the maximum number of

destinations on a route are also restricted.

The option to modify the vehicle capacity and maximum number of destinations is also incorporated, thus alternative plans can be developed and finalized by the user by his subjective judgment.

3.2. SYSTEM IMPLEMENTATION

3.2.1 SYSTEM COMPONENTS

(a) HYPER LINDO

As solving a LP/ILP is iterative process and requires considerable amount of computing as well as time, it is decided to use HYPER LINDO software. PC version of the HYPER LINDO software is being used which allow 1999 rows, 3999 columns and 1000 integer variables and 16000 non zeroes. The software is found to be quite fast. In order to run this version of HYPER LINDO 550 KB of free memory after loading DOS.

The HYPER LINDO has to be invoked a number of times in the system. And it requires the input to be in a specific format. This becomes tedious and require a considerable amount of time in coding input. In order to overcome this problem a LP formulator is developed and used. It takes data from a file and converts it into specified format. This uses the PC version of LINGO (1989) software. it also needs 550 KB of memory after loading DOS.

(b) TURBO PASCAL

The system is developed in micro computing environment using a PC/AT (Super). The operating system is DOS (ver 4.0). A range of programming language is available, but Turbo pascal is

selected due to it's inherent merits. It is one of the most structured language. It provides library facility, and the user can make his own library also. The programs compiled to the disk creates the .EXE files which can be run directly in the DOS environment.

3.2.2 SYSTEM LINKAGE

The system is developed such that it can be run directly from DOS prompt, if the system files and input are ready. BATCH files are prepared which contains a sequence of commands to be performed. It executes the required executable(.EXE) files, invokes the HYPER LINDO and LINGO software as and when needed and the solution is interpreted by the corresponding executable(.EXE) file. The executable(.EXE) program also prepare the input data files for the formulator. The linkage of the programs is shown in FIG 3.1.

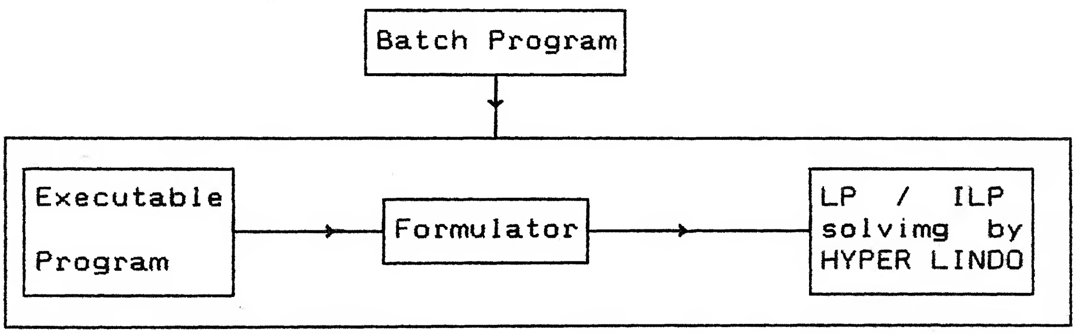


FIG 3.1 Program Linkage.

The list if the program files is given in APPENDIX A.

3.2.3 DATA STRUCTURE

The data structure plays a vital role in the system implementation and it's performance. They also govern the running time of the programs. The attempt is made to optimize the memory required and the steps required to perform various functions. Wherever the information about the center,CFA or warehouses were to be stored, array of records were used, because their number was known apriori. The fields of the record were used to store the relevant information to them.

In case of the distribution planning the distances and the saving due to clubbing of destinations were saved in the same array due to their special nature. The distance between A and B destinations is same as B and A and thus we needs to store only one. Similarly the saving by clubbing these two is same and hence stored at one memory place.

CHAPTER 4
USER MANUAL

The Decision Support System for Integrated Production Distribution Planning for consumer goods is developed in **Turbo Pascal** (Version 5.0). It is designed with assumption of minimum technical background of the user. In the following sections the systematic information has been provided for effective utilization.

4.1 GETTING STARTED

Before starting installation of the system, one should ensure that he has the following configurations available at his micro computing facility.

* Minimum 640 KB memory.
* Minimum 20 MB disk capacity.
  (To install LINGO,HYPER LINDO, TURBO PASCAL & System files)
* 8087 numeric co-processor.
* Operating system DOS (ver 4.0).
* The config.sys file in the route directory should contain the statement "FILES = 20".

In addition to these, the HYPER LINDO and LINGO software should be available. The installation of the system can be started by making a directory IPDP on the drive C on the hard disk. The drive C is chosen because generally it is available even when the micro computer has only one drive on it's hard disk. The LINGO and HYPER LINDO software should also be installed

in the same directory IPDP.

The user can check whether all the system files are there in the directory. The list of system files (BAT, EXE and UNITS), input files is given in APPENDIX A.

4.2 INPUT REQUIREMENT

The user should make ready the input information required by the system before using the system. The CFAs, products, production centers and warehouses should be numbered. The numbering of each should start from 1 and be incremented in steps of 1. The system will recognize the production centers,CFAs, products and warehouses by the numbers assigned to them only.

The input information may be classified into two categories :

1. Permanent information.
2. Temporary information.

4.2.1 PERMANENT INFORMATION

It is fixed throughout the horizon and for the time system is run. The permanent information for the system includes the distance between CFAs, warehouses and production centers, the potential warehouse locations, production capabilities and constraints of the production centers.

Following permanent files will be required to use the system :

A) PR_CEN.DAT :

The file contains the data regarding the production center name or identification, the minimum production guarantee over the planning horizon, production capacity and production cost per unit at the production center. In the file information of a center should be given in the following format :

NAME [20 CHAR]

Capacity[Real]ɓMin guarantee[Real]ɓProduction Cost[Real]

Here b represent a blank and the type shown in bracket is type of the size and type of input.

A typical file will be as follows :

```
DELHI
800.00      350.00    1.10
```

This implies that the production center is DELHI. The production capacity is 800.00 units and minimum production guarantee over the planning horizon is 350.00 units and the production cost at the production center is 1.10 per unit. Similarly the data for the other production centers are to be given. Here it should be noticed that the units for various data should be consistent.

B.) DIST.DAT

This file contains the data of distances between the production centers and the CFAs. Each row of the file contain the distance of a CFA from each production center. If the DIST[a,b] represents the distance between cfa a and center b, then the

format of the file will be as given here.

DIST[1,1] ฿ DIST[1,2] ฿ .. DIST[1,P]

DIST[2,1] ฿ DIST[2,2] ฿ .. DIST[2,P]

:

DIST[N,1] ฿ DIST[N,2] ฿. DIST[N,P]

The distances should be separated by at least one blank as shown in a typical file here.

100	250	400	125
140	350	250	1000

Here first row indicates that first CFA is at a distance of 100 units from production center 1, 250 units from production center 2 and so on. Similarly the second row implies the distances of CFA number 2.

C.) DISTIN.DAT

This file contains the data of distance in between the CFAs. Since the distance between CFA A and B is same as B and A, and between A and A is zero,we need data of a lesser number then the square of number of CFAs.

If DIST[a,b] represents the distance between the CFA a and CFA b then the file should be in the format given below.

DIST[1,1] b DIST[1,2] b .. DIST[1,N]

DIST[2,2] b .. DIST[2,N]

:

DIST[N,P]

In a file a row has distances of CFA from the other remaining one each separated with other by at least one blank. A

typical file will be as follows :

```
200   100   120   250
      125   150   300
```

Here in the first row distances of CFA number 1 from other 4 is given(assuming that there are 5 CFAs). 200 indicates that CFA 1 is at a distance of 200 units from CFA 2. The second row has distances of CFA number 2 from the rest 4 and so on.

D.) DISTWARE.DAT

This file contains the distance between warehouse location and CFAs and production centers. First row contains distances of center 1 from each warehouses and so on. Once the distances for all the production centers are over, a blank line is left and distance between CFAs and the warehouses are given.The format of the file will be as given below :

```
DIST[1,1] ƀ DIST[1,2] ..   DIST[1,W]
             :
DIST[N,1] ƀ DIST[N,2] ..   DIST[N,W]
DIST[1,1] ƀ DIST[1,2] ..   DIST[1,W]

                       :
DIST[P,1] ƀ DIST[P,2] ..   DIST[P,W]
```

Here W represents the number of the warehouses.

A typical file will be is shown below :

```
325   75   200
 :
300   50   75


375  150  100
```

Here 325 shows distance between center number land warehouse number 1. The rows after blank line shows the distance between the CFAs and warehouses. 375 is the distance between the CFA number 1 and warehouse number 1.

4.2.2 TEMPORARY INFORMATION

This information may vary with time or stage of the system. The temporary information includes the production costs, inventory carrying costs and the space available at the production centers & CFAs and demand of the CFAs. Although the costs are to be given while using the particular module of the system, some information are required to be given by the files.

Following files are required to be available before using the system :

A.) DEM.DAT

This file contains the product wise demand of various CFAs for each period. the row contains the demand of each product in a time period at a CFA. The demand should be separated by at least one blank. The format of the file will be as given here.

Demand[1,1] ƀ Demand[1,2] ƀ .. Demand[1,k]

⋮

Deman[N,1] ƀ Demand[N,2] ƀ .. Demand[N,k]

Here k represents the number of products.

A typical file will be as given below :

```
 35.00    25.00   100.00
100.00    50.00     0.00
```

Here 35.00 implies that demand of product 1 at CFA number 1 for the first time period is equal to 35.00 and 25.00 is for the product number 2 for same. The second row implies demand for the second period for all the products. Once the time periods are over the demand of second CFA is given and so on.

4.3 SYSTEM EXECUTION

Once the files required as input are ready and the installation of the system has been done, the system can be executed by typing the following command at the DOS prompt.

```
> IPDP
```

Once the command is entered, the execution starts and system shows a menu as given below :

```
1.   CFA Demand Allocation.
2.   Production Planning.
3.   Warehouse location allocation.
4.   Distribution Planning.
5.   Quit.
Give Option  [ ]
```

Here the user have to select a option and that particular function will be performed by the system. The user is advised to perform them in the sequence at least once otherwise the transparent files needed may not be available to the system.

If the user selects 1 then the demand allocation of the CFAs to the production centers is carried out. First the

aggregated product wise demand is allocated to the production centers and then it is disaggregated period wise.

If the user selects 2 then the production planning for the production centers is done. First the disaggregated period wise allocation of the demand is summed up over all the products for each period and each production center. The aggregate production plan is developed considering the production and inventory costs at the production center. The aggregated production plan is disaggregated in to master production schedule. The production is allocated to the CFAs for each time period to meet the CFA demand.

If the user selects 3 then the warehouse location and allocation is carried out. This is done considering the setup cost of warehouse and transportation from and to warehouse.

If the user selects 4 then the the distribution planning part is carried out. First the allocation of inventories to the production centers, CFAs and the warehouses is done. Once the inventories are allocated to them, schedule is prepared to ship them.

If the user selects 5 then the system stops executing and returns to the DOS prompt.

4.4 TRANSPARENT FILES

The system makes some transparent files for transfer of information and data from one module of the system to another one.Some of these are listed below with description about their content.

A.) PREAS.DAT

This transfers the information of the CFAs allocated apriori to production centers based on the subjective judgment of the user/decision maker. The information about the particular products which can not be produced at production centers are also given in this file. This information as appended in the MILP AGGPALOC before solving.

B.) WT.DAT

The number of production centers, CFAs, products time periods over the planning horizon and the products are stored in and retrieved from this file as and when needed.

C.) WLA.DAT

The information about the warehouses located and the CFAs allocated are required for the distribution planning. This is stored after obtaining the solution of the MILP LOCALLOC.

4.4 OUTPUT

Final output of the system will be containing following information :

1) CFA demand allocation.
2) Master production schedule.
3) Warehouse location allocation.
4) Distribution plan.

These information will be stored in the following files:

A.) ALLO.DAT

This file contains the information about the aggregate allocation of the product wise demand of the CFAs to various

production centers. The first row shows the demand of various products at CFA number 1 allocated to the production center number 1 over the planning horizon. Once the demand allocation for all the CFAs to this production is over the next production center is considered. A typical file will be as shown below :

155.00	25.00	100.00
20.00	0.00	100.00

Here 155.00 implies that 155.00 unit demand of first cfa for first product has been allocated to the first production center and so on.

B.) PRD. ALLO

This file contains the information about the period wise allocation of the product wise demand of the CFAs to the production centers. The first row shows the first period demand of various products at CFA number 1 allocated to the production center number 1. Once the demand allocation for all the periods is over the next CFA is considered. And as the demand allocation for all the CFAs to this production is over the next production center is considered. A typical file will be as shown below :

D.) DISG. DAT

This file contains the quantum of products to be produced in each period at each production center obtained while developing Master production schedule. Each row contains the quantities of the products in a period for a production center. A typical file is shown below :

125.00	0.00	70.00

0.00 25.00 45.00

Here 125.00 shows that the production canter number one is scheduled to produce 125.00 units of product number 1 in first period. A row shows quantities for each product in the same period for a production center. Once periods for a production center are over the next production center is considered.

E.) PRAL.DAT

This file contains the detailed report of the allocated production of the products produced in different periods at production center to the CFAs.

F.) WLOC.DAT

This file has a report indicating the number and name or identification of warehouses which have been decided to locate, among the potential locations available to.

G.) WALOC.DAT

This file has a report of the number and name or identification of CFAs which are decided to be allocated to the warehouses located.

H.) SCHED.DAT

This file contains the distribution plan of each production center and warehouse for each period indicating the destinations and quantity to be shipped by the vehicle.

I.) INV_CEN.DAT

This file has a report about the level of inventory of various products in each period at the production centers.

J.) INV_CFA.DAT

This file has a report about the level of inventory of various products in each period at the CFAs.

K.) INV_WARE.DAT

This file has a report about the level of inventory of various products in each period at the warehouses.

CONCLUSION

Integrated production distribution planning (IPDP) is a very complex process and has been topic of interest in area of Operations Management.

In this thesis, the design & implementation of a Decision Support System (DSS) for the integrated production distribution planning of a hypothetical consumer goods company has been considered. The company has a nation wide distribution network of agents & dealers and multiple production centers capable of producing a range of products.

The mathematical model is a large (0, 1) integer program, difficult to solve on micro computer. Thus strategies for the decomposition of the problem into subproblem were developed. Whenever subproblem was found to be sufficiently large to solve by LP/ILP solver, heuristic methods were developed.

The problem is semi-structured, that's why decision support system features were incorporated. User interaction is provided for the judgment which need subjective evaluation. The user is equipped to workout the problem with different sets of data and find out the effects. Based on the user information the system prepares the plan.

However, it can be observed that the optimality of the solutions may have been sacrificed in the process of problem decomposition. But the concept of optimal solution for such a

problem is not very well defined because of the probabilistic nature of demand. And for such a problem workable solution is much desirable.

The linear cost are considered in the subproblems. However in practice they may be non-linear and lead to sub optimality.

APPENDYX A

SYSTEM FILES

A PASCAL FILES

valid.pas	Vrp.pas
Dmalc.pas	Altdata.pas
Trans.pas	Inp.pas
Prd.pas	Dynm.pas
Dis.pas	Disegg.pas
Disg.pas	Modi.pas
Pr_alo.pas	Wloc.pas
Wlinp.pas	Dstr.pas

B EXECUTABLE FILES

Dmalc.exe	Altdata.exe
Trans.exe	Inp.exe
Prd.exe	Dynm.exe
Dis.exe	Disegg.exe
Disg.exe	Modi.exe
Pr_alo.exe	Wloc.exe
Wlinp.exe	Dstr.exe

C BATCH FILES

Ipdp.bat	Aloc.bat
Prd.bat	Prod.bat
Disg.bat	Praloc.bat

Distr.bat

D OTHER FILES

Alc	Alcl
Alc2	Wloc
Period	Pr_alo
Disegg	Frm.lng
Form.lng	Wloc.lng
Pral.lng	Prd.lng
Disg.lng	

REFERENCES

1. *Bedworth, D. D. and Bailey, J. E.*,"Integrated Production Control Systems : Management, Analysis and design", John Wiley, New York, 1982.

2. *Bellmore, M. and Nemhauser, G.L.*," The Travelling Salesman Problem : A Survey ", Operations Research, Vol 16, 1968, pp 538-558.

3. *Blumnfeld, D. E., Burns, L. D., Diltz, J. D. and Daganzo, C.F.*,"Analyzing Trade-offs between Transportation Inventory and production costs on freight networks", Transportation Research, Vol 19B, No. 5, 1985, pp 361-380.

4. *Bodin, L. D. and Berman, l.*, " Routing and Scheduling of school buses by computer ", Transportation Science, Vol.13, 1979, pp 113- 129.

5. *Buffa, E. S., et al.*, " Modern Production and Operations Management", 6th edition, John Wiley, New York, 1978.

6. *Cooper, L.*, " Heuristic Methods for Location Allocation Problems", SIAM Review, Vol. 6, No. 1, 1964, pp 37-52.

7. *Cooper, L.*,"Location - Allocation Problems ", Operations Research , Vol. 11, No 3, 1963, pp 331-344.

8. *Fisher, M. L. and Jaikumar, R.*," A General Assignment Heuristic for Vehicle Routing ", Networks, Vol.11, 1981, pp 109-124.

9. *Gillet, B.E. and Miller, L. R.*," A Heuristic ALgorithm for the Vehicle - dispatch Problem",Operations Research, Vol 22, 1974,pp 340-349.

10. *Golden, B.L., et al.*," Implementing Vehicle Routing Algorithms ", Networks, Vol 7, 1977, pp 113-148.

11. *Jacobson, S. K., and Madsen, O. B.G.*, " A Comparative Study of Heuristics for a two level Routing Location Problem",European Journal of Operations Research, Vol 5, 1980, pp 378- 387.

12. *Johnson, L.A. and Montgomory, D. C.*, " Operations Research in Production Planning, Scheduling and Inventory Control", John Wiley, 1974.

13. *Love, R. F. and Juel, H.*, " Properties and Solution Methods for Large Location Allocation Problems ", Journal of Operations Research Society , Vol. 33,1982,pp 443-452.

14. *Naghelhout, R. V. and Thompson, G. L.*, " A cost operator Approach to Multistage Location - Allocation ", European Journal of Operational Research,Vol. 6,1981,pp 149-161.

15. *Nambiar, J.M., Gelders, L.F., et al.*, " A Large Scale Location Allocation Problem in the Natural Rubber Industry", European Journal of Operational Research, Vol.6, 1981, pp 183-189.

16. *Perl, J. and Daskin , M. S.*, " A Warehouse Location - Routing Problem", Transportation Research, Vol 19B, 1985, pp 381- 396.

17. *Shyam,B.*,"Integrated production distribution planning for consumer goods industry",M. Tech. thesis,IIT Kanpur,1990.

18. *Sprague,R.H. Jr and Watson,H.J.*,"Decision Support system : Putting theory into practice",Prentice hall,New Jersey, 1986.

19. *Vollman, T. E. and Barry, W.L.*, " Manufacturing Planning and Control Systems", Galgotia, New Delhi, 1989.

DISCUSSION

The following points were observed in discussion during the final seminar :

* It was asked how close the system is to an ideal Decision Support System. Most of the features of the DSS are incorporated in the system. Still due to use of HYPER LINDO and LINGO to solve the integer and linear programs, it requires lot of time. The modules can be further simplified by developing heuristic methods.
* Clarification about the alternate demand allocation plans was sought. Alternate plans can be developed by changing the cost parameters as well as the right hand side coefficients of the constraints in the mathematical programs. But for the problems at later stage, the right hand sides are obtained from previous problems and thus the only parameters which can be changed are costs.
* The system can be used for non consumer goods also by making some modifications. Some of the constraints will have to be relaxed. Demand profiles will have to be developed from the accumulation of orders or the forecasting system. distribution planning will be of less importance in such case. Production may have to be done in lots.